Detecting Dysfunctional Behavior in Adolescents: The Examination of Relationships Using Neural Networks

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We describe a neural network that models the effect of personality, social, and environmental variables on hopelessness in adolescents. A sensitivity analysis suggests the effect that variation in each of the input variables will have on the output. Clinical implications are that health professionals can focus their attention on the variables most likely to impact upon the outcome.

INTRODUCTION

Several researchers have discussed the relationship of hopelessness with depression and other psychiatric disorders. The topic is of interest particularly in adolescents because of the association between hopelessness and suicidal tendency [1-6]. Additionally, hopelessness is also related to other kinds of psychopathology in children and adolescents [7-10].

To assist in identifying these relationships, neural networks seem particularly appropriate, as they can quantify complex mapping in a compact and elegant manner [11-12]. Neural networks have been used in general psychiatry in a broad range of problems. They have modeled brain functioning in schizophrenia [13], have classified PET scans [14], and have modeled humans on a continuous performance task under CNS stimulants [15].

The purpose of this study was to identify the most important mental health variables from a set of personality, family support, and social support variables that related to hopelessness by modeling these relationships using a neural network. We desired to see which variables made the greater contributions and determine how changing them affected hopelessness.

METHOD

Sample

One hundred fifty adolescents were selected from a systematic sample of over 1700 high school students in a midwestern town, stratified a priori to obtain equal numbers of males and females at each of three ages: 14, 15, and 16 [16]. One hundred forty-two were white, six were black, and two were oriental. Data from seven were discarded due to missing information. There were no differences in social class, age, or family status between those who participated in the study and those who did not.

Instruments

Instruments included the Millon Adolescent Personality Inventory (MAPI) [17]; the Diagnostic Interview for Children and Adolescents (DICA) [18]; the Parental Bonding Questionnaire [19]; the Social Support Questionnaire [20], and the Hopelessness Scale for children [4].

We included the following Millon personality scales: Cooperative, Forceful, Personal Esteem, Sensitive, Social Tolerance, Family Rapport, Impulse Control, and Societal Conformity. The rest of the Millon scales were omitted from the analysis because they were judged to be less relevant to the problem at hand. The following descriptions of the personality scales are excerpted from the Millon Adolescent Personality Inventory Manual [17]. In the Cooperative scale, higher scores suggest being soft-hearted and sentimental. In the Forceful scale, higher scores denote being strong-willed, tending to lead and dominate others. High scores in Personal Esteem mean greater struggle by the individual for social approval. In the Sensitive scale, higher scores denote discontentment and pessimism. In addition to the personality scales, the Millon also has scales of expressed concerns. In the Social Tolerance scale, higher scores mean more pathology, and are associated with such items as being alone rather than being sociable, and taking advantage of people. Higher scores in Family Rapport mean more pathology and are characterized by such items as wanting to be away from home and destructive criticism from parents. Higher scores on the Impulse Control scale indicate more compulsive behavior. In the Societal Conformity

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scale, higher scores mean more pathology, less adjustment, and more aggressiveness. The parental bonding and social support questionnaires provided the following scales : Parental Care and Parental Overprotection, and Social Support (number of supportive people) and Satisfaction as being probable factors in hopelessness. The binary DICA diagnosis scales included were: oppositional disorder, conduct disorder, anxiety, major depression and dysthymic disorder, combined, and alcohol and drugs, combined. We also included a Psychosocial Stress scale from the DICA.

Neural network modeling and analysis

We trained a multilayer back propagation neural network with the responses of the adolescents, and subsequently performed a sensitivity analysis. Back-propagation is a mapping network that learns an approximation to a nonlinear function, y = f(x), from sample (x,y) pairs by propagating the errors successively back through the layers. The equations for a back-propagation network have been derived by Rumelhart & McClelland [21]. The back propagation network learns by changing its weights to minimize the sum of squared errors between its output and the supplied target data. We also validated the training process to ensure that the network mapped the relationships well. The network that modeled the complex relationships between the variables in the study had 19 inputs, 1 output, and 20 and 10 neurons each in the two hidden layers. The inputs were the responses of 143 adolescents to the MAPI, DICA, Parental Bonding Questionnaire, and the Social Support Questionnaire. The output was the Hopelessness score from Kazdin's Hopelessness Scale for children. The adolescents' responses to the various variables formed 143 training "patterns" for the neural network. All the required code was developed in-house using the C programming language. The data were normalized before training the neural network. The errors dropped rapidly during training and were less than 10% in prediction of the Hopelessness score for each of the 143 adolescents after 4,000 epochs. Though further training allowed reduction of error to less than 0.1%, this was avoided to prevent a phenomenon called "overtraining" which affects the ability of the neural net to capture general trends in the data.

After being trained in the manner described above, a neural network acts as an expert for predictions. If a new case is presented to the network, it should be able to predict the hopelessness score for that adolescent, based on the training that it has received, as an expert would do. While an expert would probably have problems drawing inferences from such a large number of variables, a neural network handles the complexity easily. In addition, the neural model can describe the relative importance of each input variable, which may be a difficult problem for an individual expert.

Sensitivity

The network was presented with the "case history" of each adolescent, and one aspect of the "case history" was perturbed at a time by a fixed amount to observe the change in the network's output, thus quantifying the sensitivity of the system. The result represents the change in hopelessness for a specified change in any of the input variables. For instance, the percentage change in hopelessness (output) can be estimated if family support (input) is doubled. The methodology thus quantifies the relative importance of each of the personality and support variables on hopelessness.

The sensitivity analysis revealed the dominant factors that affect hopelessness. We perturbed each of the Millon, the DICA diagnoses, Parental Bonding, and Social Support scales to study their effect on the Hopelessness scale. The sensitivity analysis considers one variable at a time, keeping the remainder constant. Each variable was perturbed across its range for each adolescent and a rate of change of hopelessness, i.e., a measure of sensitivity, was computed for each variable. The rate of change was then averaged over all the cases.

Statistical comparison

We also compared our results to a linear statistical model, with hopelessness as the dependent variable and the 19 input variables as independent variables. However, because multicollinearities inflate the variances of predicted values and of parameter estimates, we did a principal components regression, using principal components as the independent variables in the model.

RESULTS

Table 1 lists the slopes for each variable at a

representative point, the "unperturbed" value, of the output across the range of the input variable. These slopes have been normalized by multiplying by the range of the input variable.

Referring to the values in Table 1, the following variations are relatively large and are therefore of special significance. High scores on Forceful imply greater pathology and are associated with aggressiveness and domination. Thus a forceful person is less likely to be hopeless.

Higher scores in Sensitive and Social Tolerance are associated with greater pathology, and were related to greater hopelessness. Higher scores in Impulse Control are also associated with greater pathology, but Hopelessness decreased as Impulse Control increased, perhaps because Impulse Control is associated with aggressiveness. Similar to forceful, Conduct Disorder was also negatively related to hopelessness. The use of alcohol and drugs tended to be related to an increase in hopelessness.

Table 1: Input Slopes

Forceful	-10.8
Sensitive	8.2
Social Tolerance	6.2
Impulse Control	- 4.2
Conduct Disorder	- 3.6
Alcohol & drug	3.0
Family Rapport	2.9
No. of Supportive People	- 2.5
Societal Conformity	2.3
Cooperative	- 1.9
Oppositional	- 1.9
Depression (MDD & DD)	1.9
Personal Esteem	- 1.3
Parental Overprotection	1.0
Satisfaction Rating	- 1.0
Sex	- 0.9
Psychosocial Stress	- 0.3
Parental Care	0.2
Anxiety	0.1

Validation study

To test the efficacy of the network training, 80% of the adolescents were randomly selected for "training" the network, and the remaining 20% were used for validation. The network predictions agreed with the actual Hopelessness score within 25% for 79% of the adolescents and within 50% for 93% of the adolescents.

Statistical analysis

A principal components analysis of the 19 variables yielded one eigenvalue accounting for 33% of the variance, and a second accounting for 11%. A scree test (involving the graphic display of eigenvalues) suggested that eigenvalues beyond two would be less important. Variables with large weights on the first eigenvector included Forceful, Sensitive, Family Rapport, Impulse Control, and Societal Conformity. Variables with large weights on the second eigenvector included Anxiety, Cooperative, Forceful, and Personal Esteem.

A regression analysis on the 19 components had significant tests of regression parameters on seven of the components; the first two parameters were significant at the .001 and .01 levels, respectively.

Social Tolerance, which had the third largest weight in the neural network analysis was not identified as important by this statistical analysis. Conduct Disorder and Alcohol were in the fourth component, whose regression parameter was also significant.

The regression analysis identified Anxiety as important to hopelessness, whereas findings from the neural network analysis would suggest that clinician attention to anxiety would be unproductive in reducing hopelessness.

DISCUSSION

These results imply that hopeless adolescents should be more assertive, should be more sociable, and should be less sensitive. The magnitudes of the slopes describe the relative importance of the input variables on the output variable.

This investigation and model validation demonstrate that the application of artificial neural networks is useful in adolescent psychiatry. This approach enhances the clinician's and the researcher's ability to study and handle multivariate problems, and enables us to see how a change in one input variable may potentially affect the outcome. It is not known whether certain personality traits predispose the individual to hopelessness or the opposite. We also present further evidence of the impact of the environment on the youth. Studies using larger numbers of subjects would have greater accuracy of responses. Although a specific study pertaining to hopelessness is reported in this paper, the sensitivity approach outlined for determining the relative importance of factors that cause or affect a

certain phenomenon or property using neural networks has more general applicability.

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